Statistical Analysis of CRM-Simulated Year-long Cloud Properties and Validation against ARM SGP Observations

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The role of cloud systems in the general circulation

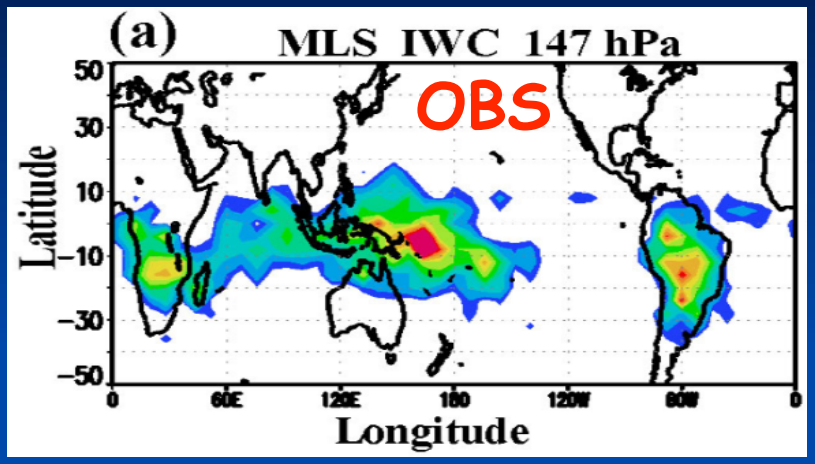
* Coupling dynamical and hydrological processes through the latent heat of condensation and evaporation and the redistribution of heat, moisture and momentum

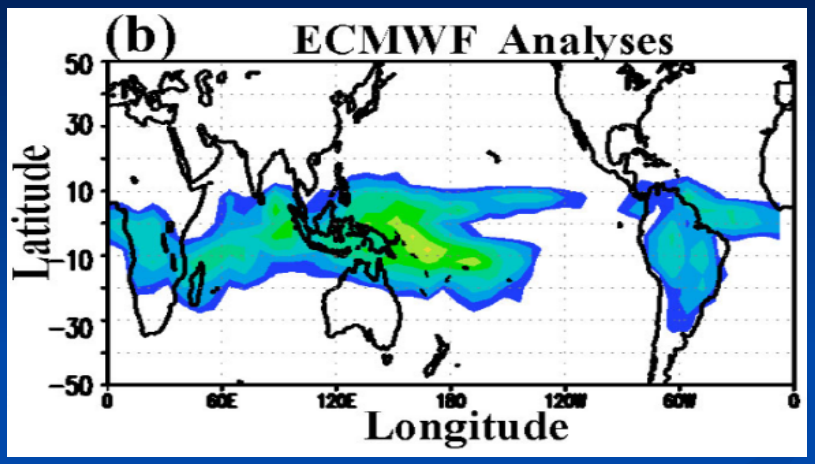
* Coupling radiative and dynamical-hydrological processes through the reflection, absorption, and emission of radiation

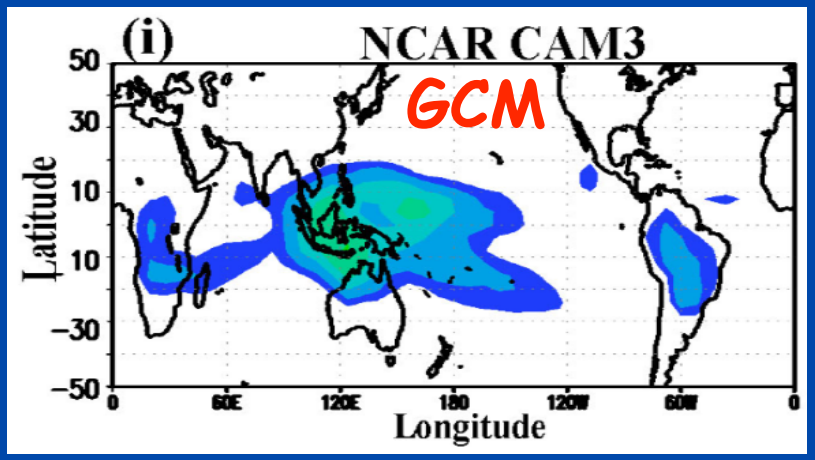
* Affecting hydrological processes through precipitation

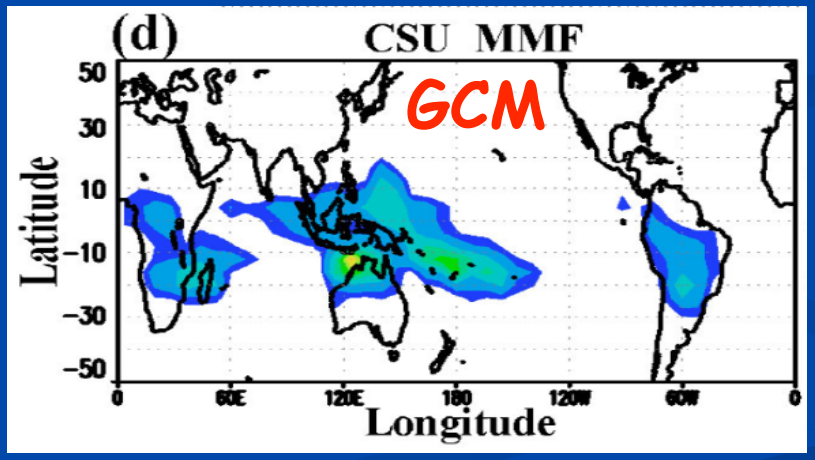
* Affecting the atmosphere-ocean coupling through modification of radiation and boundary-layer processes

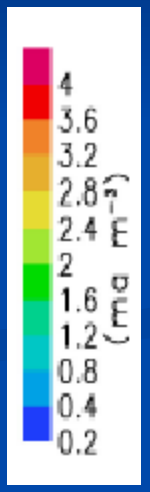
Ice water content (mg m^{-3})







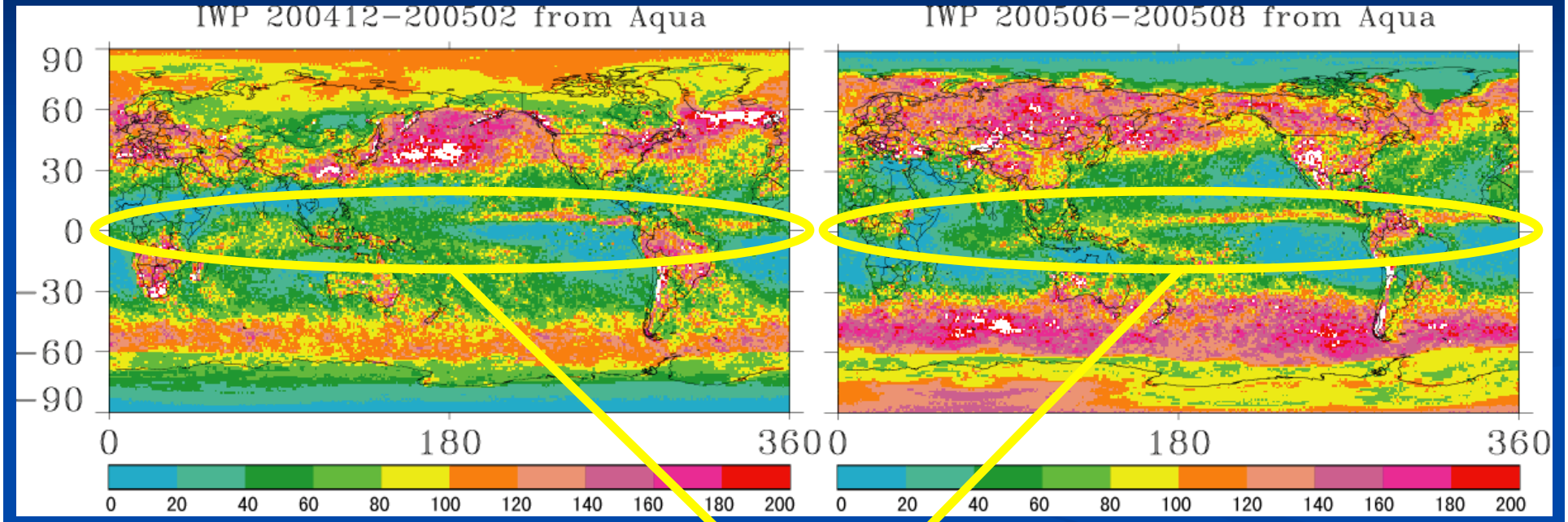




Li et al. (2005, GRL)

Ice water path (IWP g m^{-2}) from Aqua

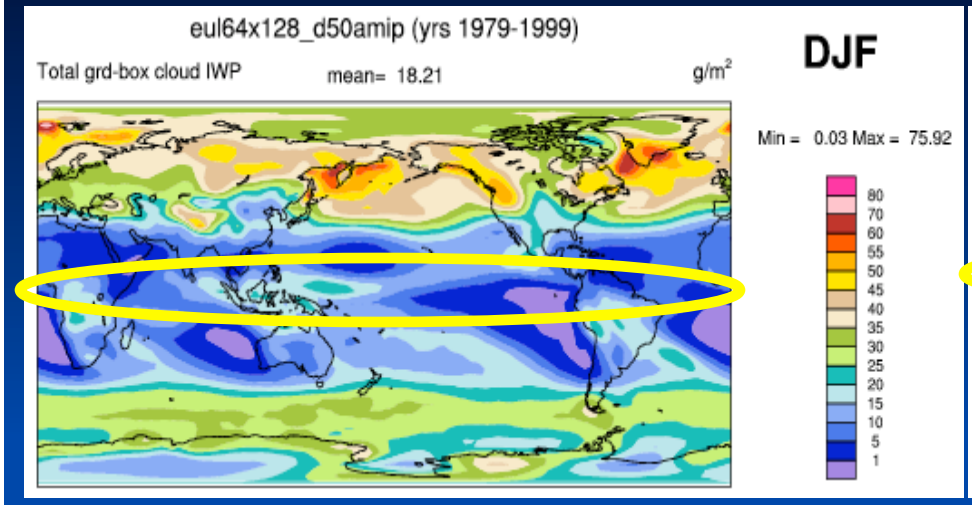
DJF JJA

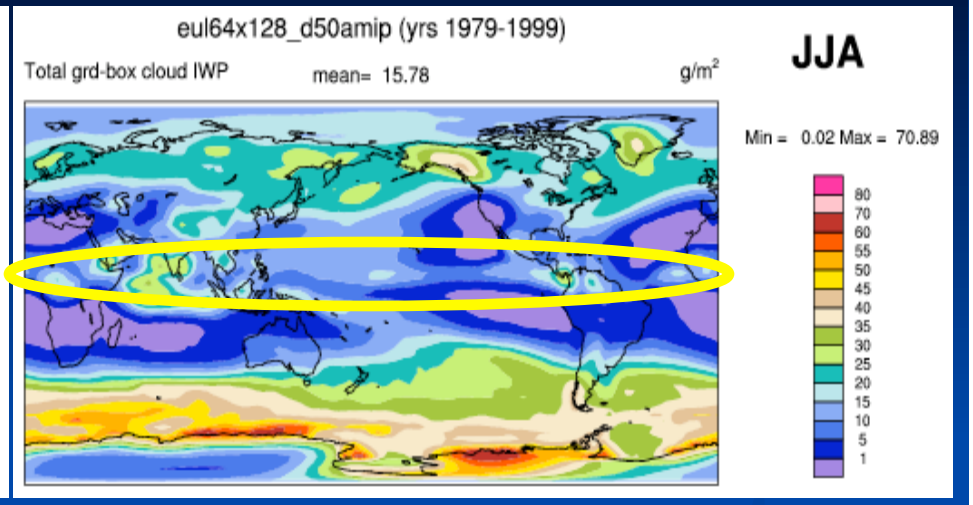


Larger than 40 W m^{-2}

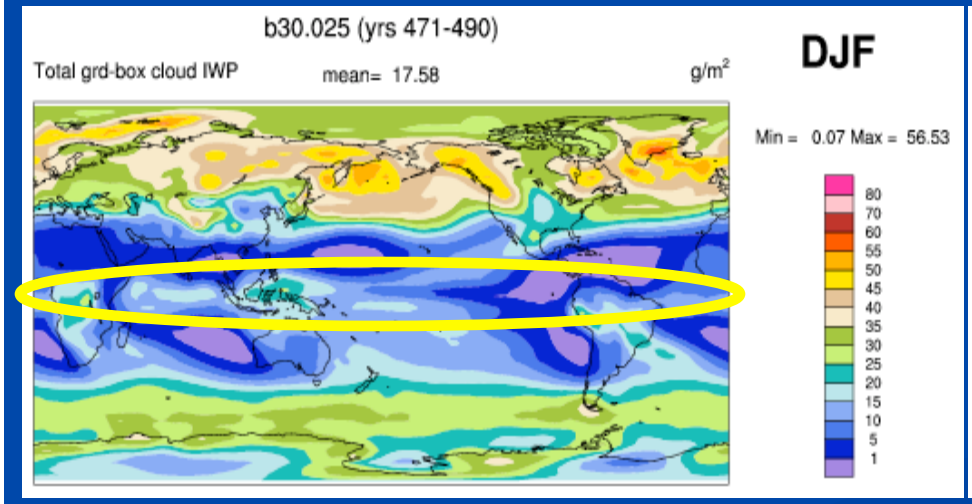
From Bing Lin and Pat Minnis (NASA/LaRC)

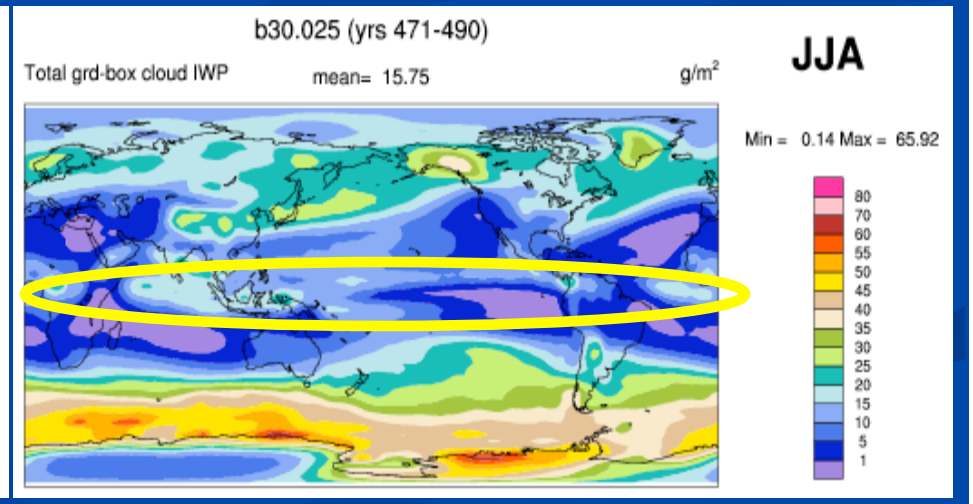
Ice water path from NCAR CAM3





Ice water path from NCAR CCSM3





ISU Cloud-Resolving Model (CRM):

(Grabowski et al. 1996, JAS; Wu et al. 1998, 2008, JAS)

* Cloud Dynamics:

Clark-Hall finite-difference formulation of anelastic and nonhydrostatic equations (Clark et al. 1996)

* Model Physics:

1. Cloud liquid and ice microphysical schemes (Kessler 1969; Koenig and Murray 1976)
2. Radiation parameterization from NCAR GCM (Kiehl et al. 1996)
3. Eddy diffusion parameterization (Smagorinsky 1963)

* Observed large-scale forcing:

$$\left(\frac{\partial \theta}{\partial t}\right)_{lsf} = -U\frac{\partial \Theta}{\partial x} - V\frac{\partial \Theta}{\partial y} - W\frac{\partial \Theta}{\partial z}$$

$$\left(\frac{\partial q_v}{\partial t}\right)_{lsf} = -U\frac{\partial Q_v}{\partial x} - V\frac{\partial Q_v}{\partial y} - W\frac{\partial Q_v}{\partial z}$$

Θ, Q_v, U, V, W are observed temperature, moisture, and wind fields

ARM value added observational products:

* Continuous forcing Data at the SGP site (Xie et al. 2004, JGR)

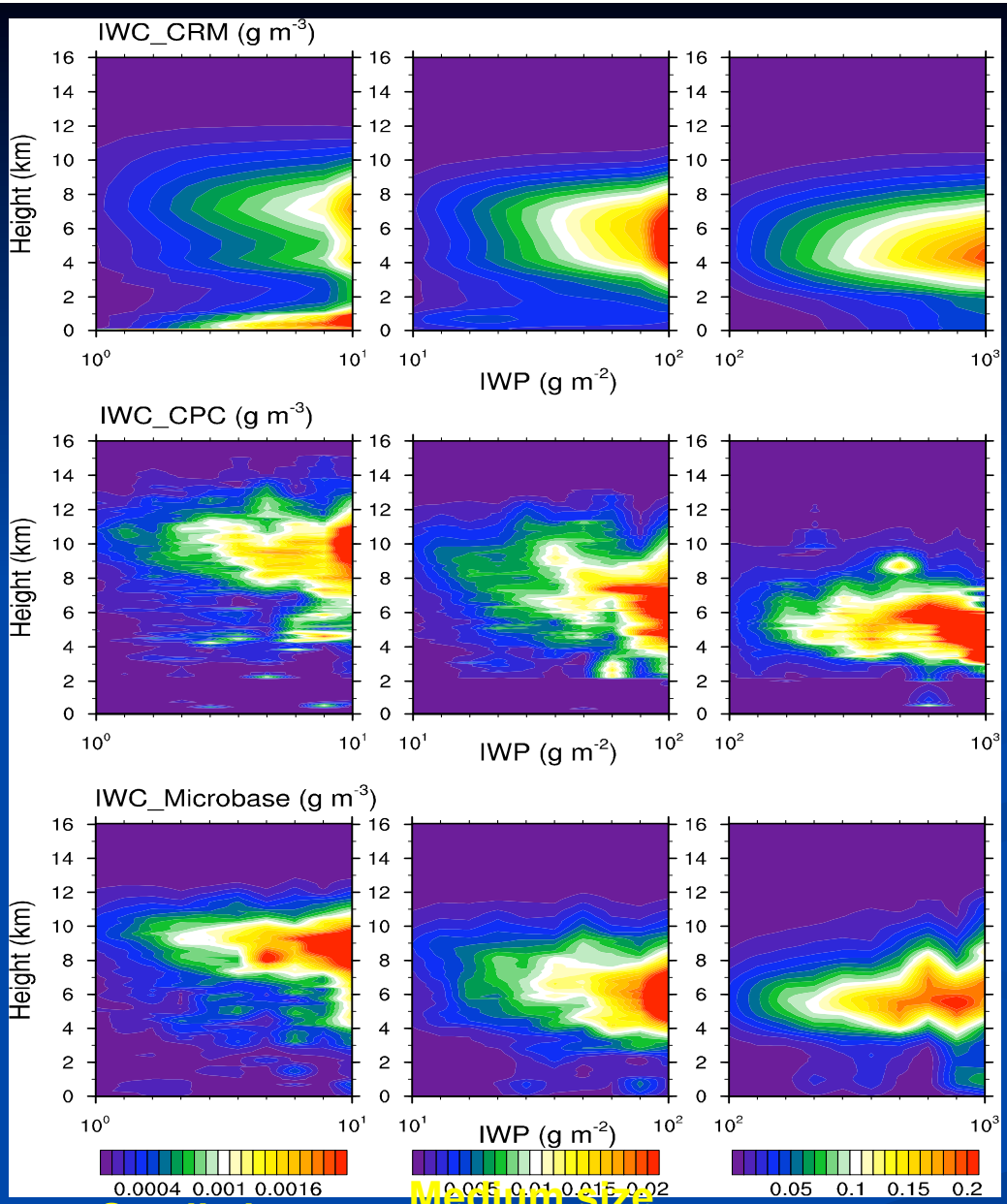
* Column Physical Characterization (CPC) product (Mace et al. 2006, JGR)

* Continuous baseline microphysical retrieval (MICROBASE) (Miller et al. 2003, Thirteenth ARM science team meeting proceedings)

* Multifilter rotating shadowband radiometer (MFRSR) (Min et al. 2004, JGR)

Vertical profiles of Ice Water Content under overcast and non-precipitating conditions during year 2000

Height (km)



CRM

CPC

MICROBASE

Small size (1-10 g m^{-2}) Bin width (1 g m^{-2})

Medium size (10-100 g m^{-2}) Bin width (10 g m^{-2})

Large size (100-1000 g m^{-2}) Bin width (100 g m^{-2})

Park et al. (2009)

Vertical profiles of Liquid Water Content under overcast and non-precipitating conditions during year 2000

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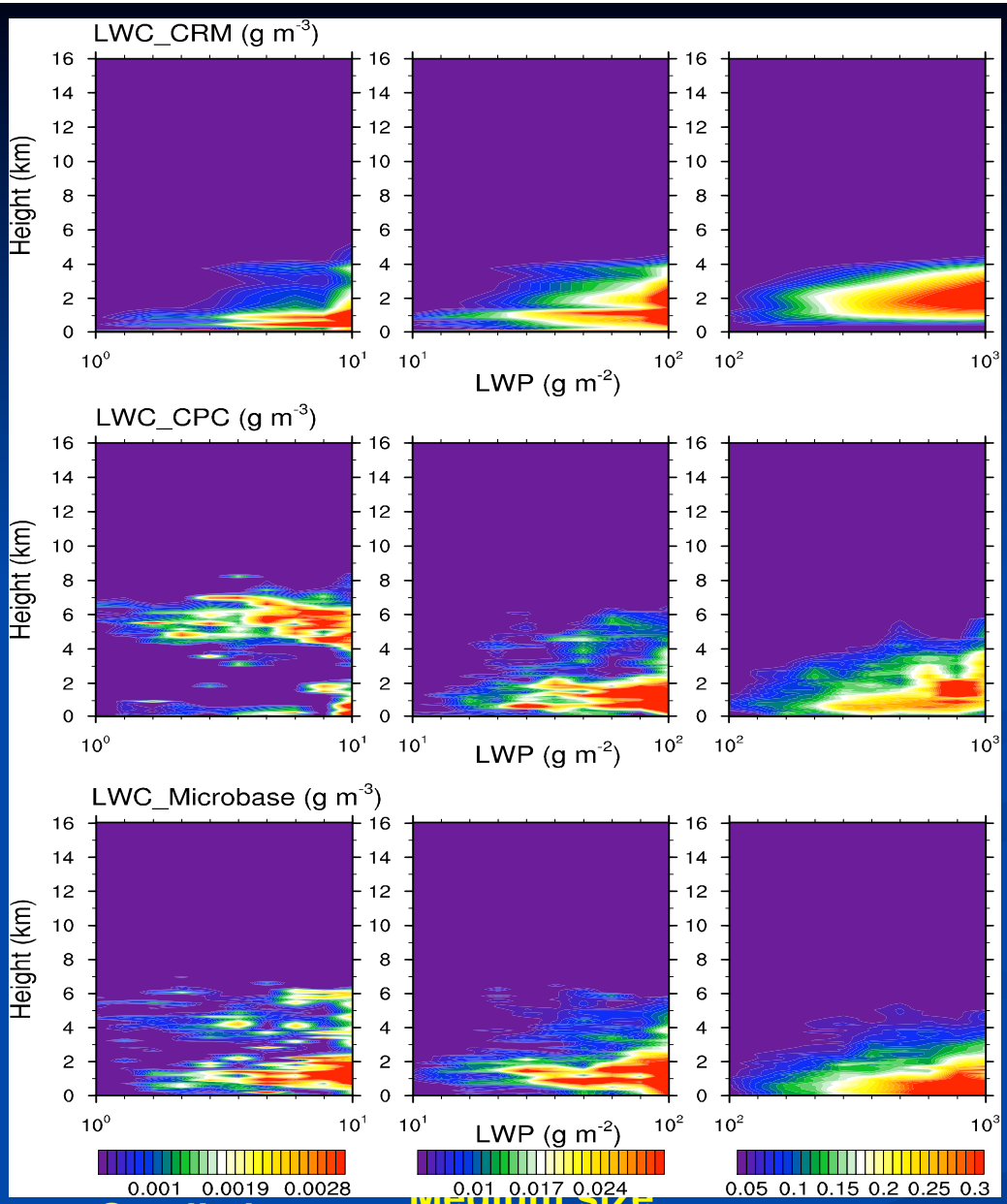

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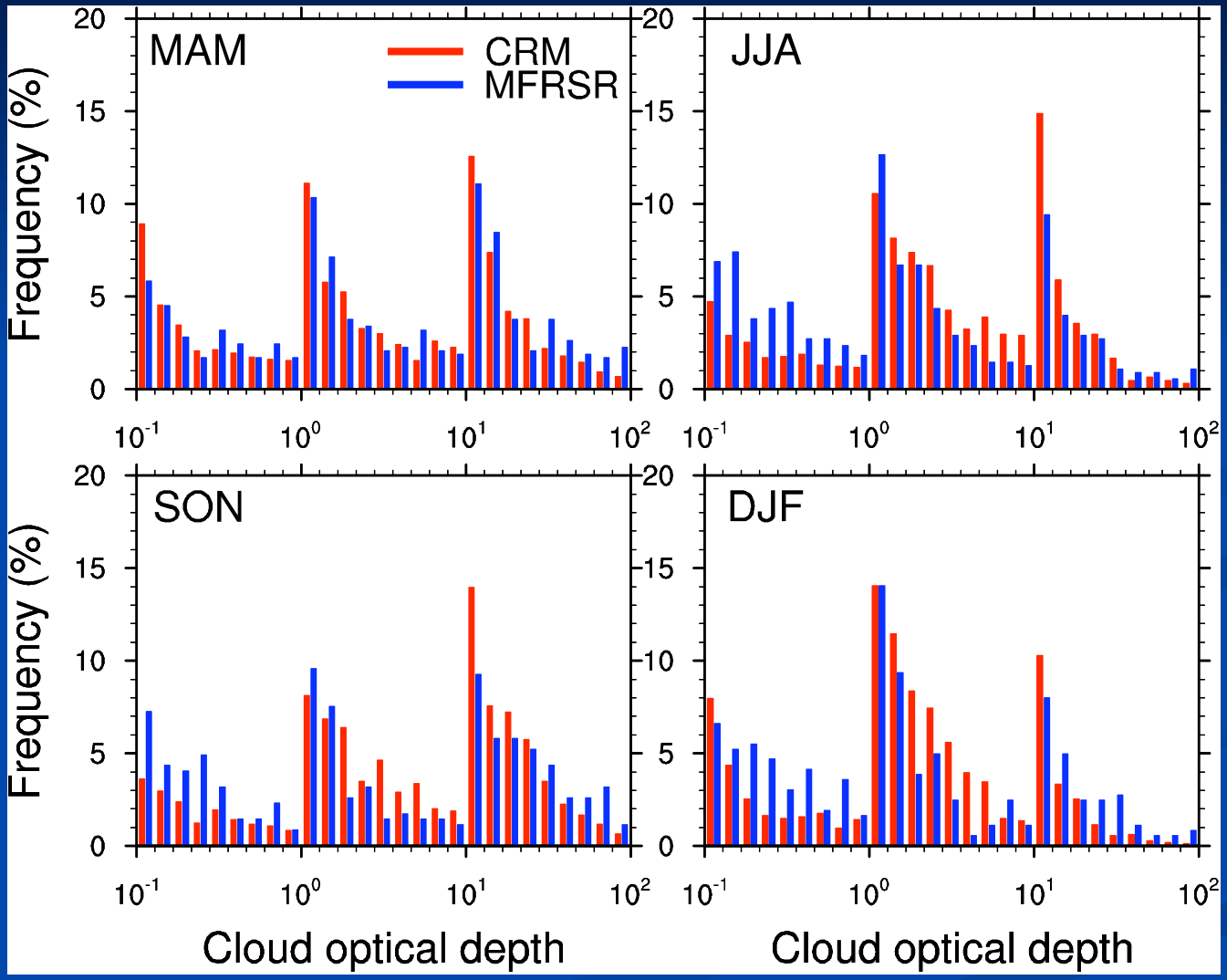
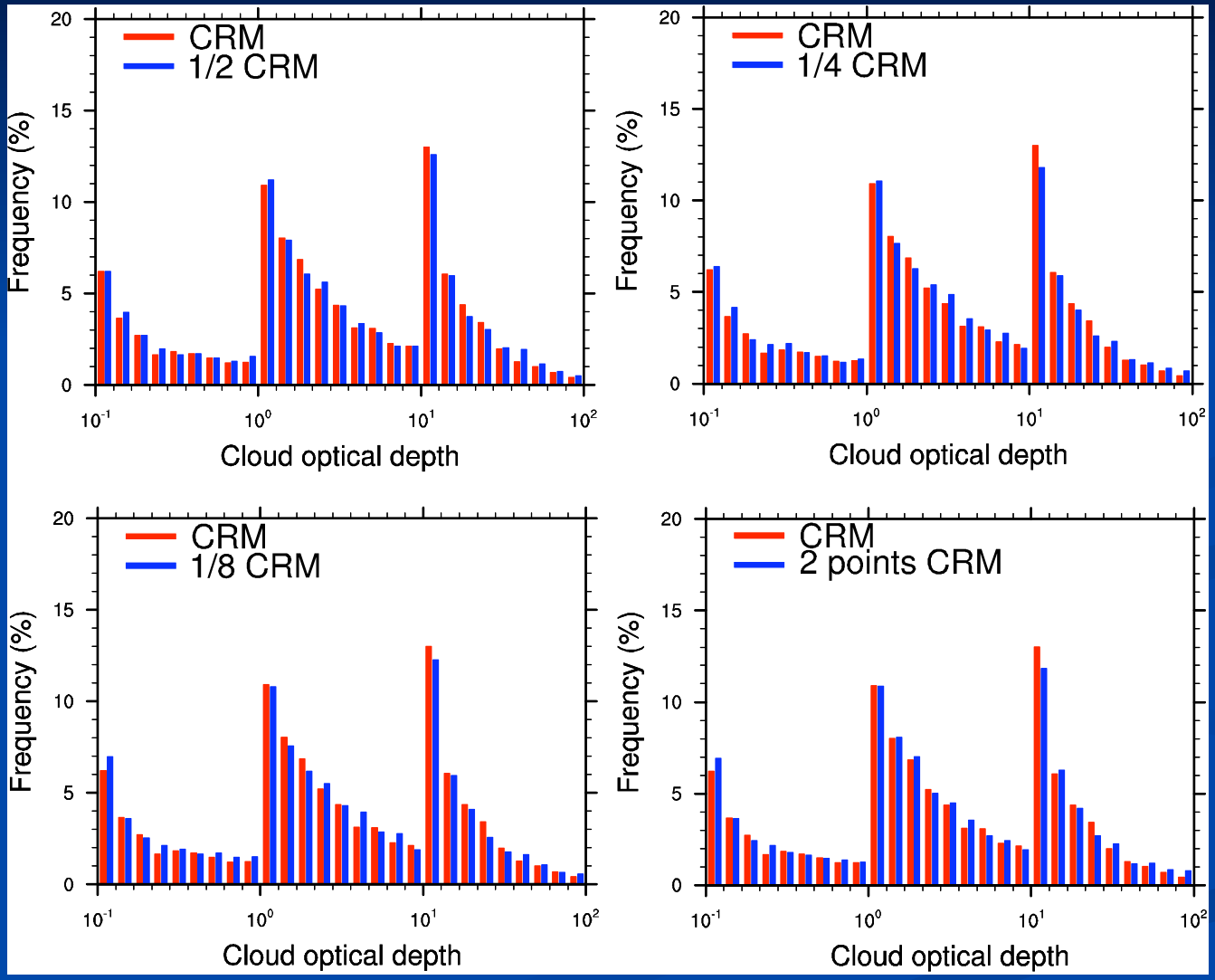
Park et al. (2009)

All-sky condition during daytime of year 2000



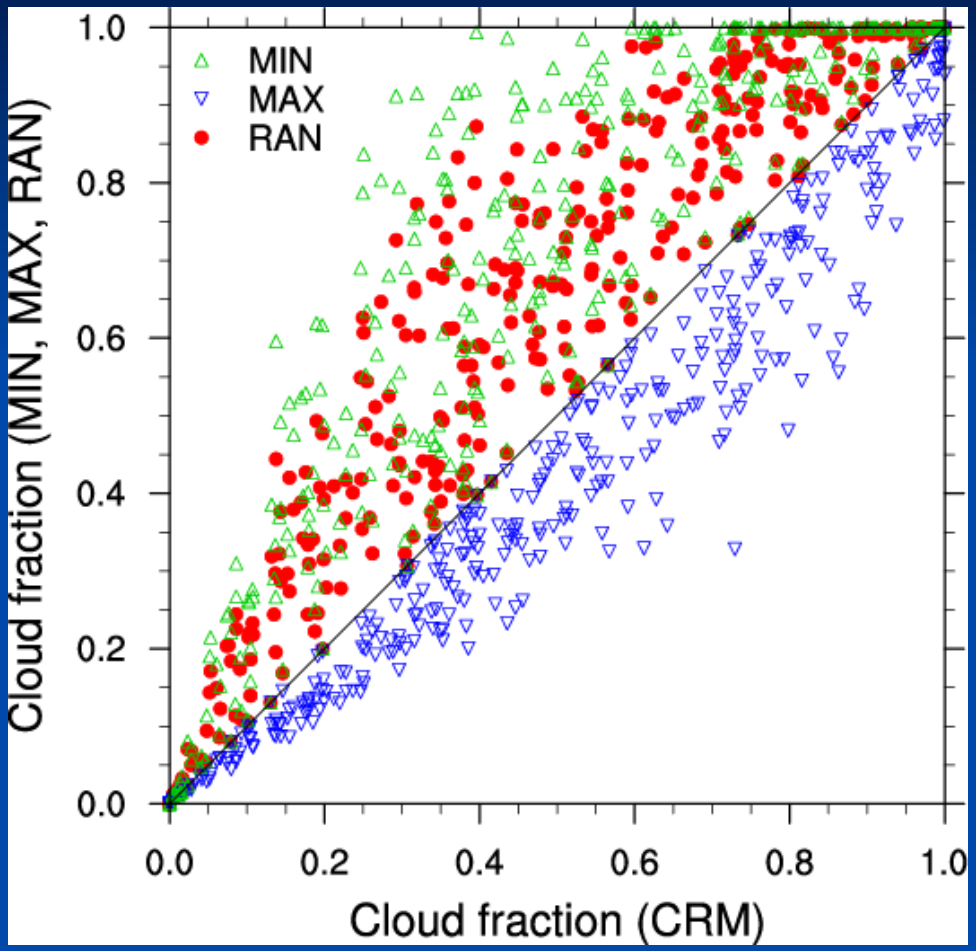
Park et al. (2009)

All-sky condition during daytime of year 2000



Park et al. (2009)

All-sky condition during year 2000



$$TC_{MIN} = Min\left(\sum_{i=1}^{n} A_i, 1\right)$$

$$TC_{MAX} = Max(A_1, A_2, \cdots\cdots, A_n)$$

$$TC_{RAN} = 1 - (1 - A_1)(1 - A_2)\cdots\cdots(1 - A_n)$$

The vertical distribution of liquid and ice water content and the frequency distribution of cloud optical depth simulated by the CRM is generally consistent with those from ARM observational estimates (CPC, MICROBASE and MFRSR).

The vertical overlap of clouds in the year-long CRM simulation can not be simply represented by the existing overlap assumptions (a paper is in preparation).

In collaborating with Dr. Dick Farley, a new microphysical scheme is being implemented in ISU CRM, which assumes two classes of liquid particles (cloud water and rain), and four classes of ice particles (cloud ice crystals, snow, graupel, and hail). For each particle class, two moments of the particle size distribution (number concentration and mixing ratio) are predicted. The impact of aerosols on the formation and development of clouds can be investigated with the improved CRM and aerosol observations.